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Triadimefon and *Pisolithus* Ectomycorrhizae Affect Second-Year Field Performance of Loblolly Pine

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ABSTRACT

Survival and growth of loblolly pine 2 years after planting on a productive site (site index 80) in South Carolina were not affected by suppression of naturally occurring ectomycorrhizae caused by triadimefon spraying in the nursery to control fusiform rust. However, seedlings with abundant *Pisolithus tinctorius* ectomycorrhizae (Pt index 84) sprayed with fermate in the nursery were significantly larger after 2 years than seedlings with lesser amounts of *Pisolithus* ectomycorrhizae sprayed with triadimefon and seedlings with naturally occurring ectomycorrhizae sprayed with either fungicide. Seedlings of the fermate-*Pisolithus* ectomycorrhizae treatment had significantly more starch in roots than other seedlings at planting. Adequate monthly rainfall prevented severe soil moisture stress. Nearly 23 percent of seedlings sprayed with triadimefon in the nursery developed fusiform rust galls of field origin, while only 16 percent of seedlings sprayed in the nursery with fermate developed such galls.

Keywords: *Pinus taeda*, Bayleton®, fusiform rust, rust susceptibility.

The systemic fungicide triadimefon (Bayleton®) is used in bare-root nurseries throughout the South to control fusiform rust disease caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme* on loblolly (*Pinus taeda* L.) and slash (*P. elliotii* Engelm. var. *elliotii*) pine seedlings. This fungicide controls rust, but it suppresses development of naturally occurring ectomycorrhizae (Rowan and Kelley 1986; Snow and others 1979) as well as those formed by *Pisolithus tinctorius* (Pers.) Coker & Couch (Pt) inoculated into nursery beds (Marx and others 1986). Suppression of ectomycorrhizal development is caused

by high concentrations of residues of triadimefon and its isomer triadimenol in feeder roots and, in the case of Pt, by a decrease in survival of vegetative inoculum in soil (Marx and Cordell 1987; Marx and others 1986). The higher the dose, the greater and longer the suppression. Kelley and others (1984) recommended that the dose be reduced from 0.42 or 0.56 kg a.i./ha to 0.28 kg a.i./ha per application. Marx and Cordell (1987) later found, however, that doses as low as three sprays each at 0.14 kg a.i./ha suppressed Pt and naturally occurring ectomycorrhizal development on both pine species for most of the nursery growing season.

Concern has been voiced (Marx and Cordell 1987; Marx and others 1986) that ectomycorrhizal suppression may harm field performance of seedlings, especially on stressed sites or in stressed growing seasons. Recently, Rowan and Kelley (1986) found no significant effects of triadimefon nursery sprays on first-year survival or growth of loblolly or slash pine seedlings on five diverse reforestation sites in Alabama and Georgia.

The purposes of the research reported here were: (1) to determine the effects of triadimefon suppression of Pt or naturally occurring ectomycorrhizae on 2-year survival and growth of loblolly pines planted on a good-quality reforestation site, and (2) to follow the development of fusiform rust on the seedlings over the same period.

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Materials and Methods

Loblolly pine seedlings (South Carolina Piedmont improved seed orchard source) were grown at the Taylor Forest Tree Nursery, Trenton, SC, as described by Marx and others (1986). Nursery treatments were: (1) three sprays of 0.56 kg a.i./ha of triadimefon during rust season or (2) applications of fer-mate during rust season in combination with either Pt inoculation or naturally occurring mycorrhizal fungi. Seedlings were lifted, graded, and measured as reported earlier (Marx and others 1986). All needles were removed from 1,500 seedlings from each of the four treatment combinations (300/replicate) and stems were examined for fusiform rust galls; gall height from the root collar was also recorded. Another 750 graded seedlings/treatment combination (150/replicate) were packed in kraft paper seedling bags containing wet hydromulch and stored at 5 °C for 7 days before outplanting. Roots of an additional 25 seedlings/replicate (total 125 seedlings/treatment) were excised, frozen within 24 hours, and assayed² for ethyl alcohol soluble carbohydrates and starch (Worley 1979).

The planting site is on the Savannah River Forest Station, Aiken, SC. The previous stand of longleaf pine (*P. palustris* Mill.) was clearcut in early 1982, and the site was sheared and raked in September 1983. Site index is 80 for loblolly pine at age 50, and the soil is sand or loamy sand for 1.3 to 1.6 m over sandy loam to sandy clay loam. Soil series are Blanton, Fuquay, and Ailey.

Seedlings were planted on January 11 and 12, 1984, on 2.6- x 2.6-m spacing with a Whitfield planter. There were three 50-seedling rows/treatment in each of five blocks. The three treatment rows/block were separated from other treatment rows by a border row of nursery-run loblolly pine seedlings. Blocks of the four treatments were also separated by three rows of nursery-run seedlings. A total of 3,000 measurement seedlings were planted.

²Assay done by Marshall Bush, Poultry Sciences Laboratory, University of Georgia, Athens.

Height and root-collar diameter (RCD) were measured 1 month after planting and in January after the first and second growing seasons. Field measurements were converted to seedling volume (height x RCD²) and plot volume indices (PVI = total of all seedling volumes in plot) following established procedures (Hatchell and others 1985).

The incidence of fusiform rust galls and their location on each seedling were recorded during seedling measurements. No galls higher than 18 cm above groundline were found on seedlings in the nursery. Stem galls less than 20 cm above groundline, therefore, were classed as "latent nursery infections," while galls located higher on the stem and on branches were classed as "field infections."

All data were subjected to analysis of variance, and significant differences among means were identified with Duncan's new multiple range test at $P = 0.05$. Monthly rainfall at the study site was estimated by averaging readings from two rain gauge stations located about 8 km south and 4 km northeast of the site.

Results

Seedling size at planting did not differ significantly by nursery treatment (table 1). Seedlings with the most Pt ectomycorrhizae (Pt inoculation and fer-mate spray) had significantly more starch in their roots than other seedlings, however.

After 2 years, there were no differences in seedling survival among nursery treatments (table 2). Seedlings with the most Pt ectomycorrhizae at planting, however, were significantly larger than other seedlings. Seedling and plot volumes for these Pt seedlings were 18 and 22 percent greater, respectively, than those for other seedlings.

Rainfall was adequate and evenly distributed for the first several months after planting (table 3). For September through November of the first growing season, rainfall was below average. Total rainfall during the second year

Table 1.--Preplanting characteristics of loblolly pine seedlings sprayed with triadimefon or fermate and with Pisolithus tinctorius (Pt) or naturally occurring (NI) ectomycorrhizae¹

Treatment	Height	Root collar diameter	Ectomycorrhizal condition			T/R ³	Root carbohydrate	
			Pt	All fungi	Pt index ²		Starch	Soluble
				%	%			
	cm	cm	%	%			mg/g	
Fermate + Pt	21.4a	0.43a	58a	69a	84a	1.78a	187a	74a
Fermate + NI	21.0a	0.42a	0c	63a	0c	1.77a	138b	75a
Triadimefon + Pt	19.8a	0.40a	6b	33b	5b	1.68a	149b	69a
Triadimefon + NI	19.3a	0.39a	0c	24b	0c	1.84a	136b	69a

¹Means in a column sharing a common letter are not significantly different according to Duncan's multiple range test ($P=0.05$).

²Pt index = A(B/C) where A = percent of seedlings with Pt ectomycorrhizae, B = average percent of feeder roots with Pt ectomycorrhizae (including 0 percent for those without Pt), and C = average percent of feeder roots with ectomycorrhizae formed by Pt and other fungi.

³Top/root ratio (T/R) is based on fresh weights of 125 seedlings/treatment used in root carbohydrate analysis.

Table 2.--Second-year field performance of loblolly pine seedlings with Pisolithus tinctorius (Pt) or with naturally occurring (NI) ectomycorrhizae and sprayed with triadimefon or fermate in the nursery¹

Treatment	Survival	Height	Root collar diameter	Seedling volume index ²	Plot volume index ³
	%	cm	cm	cm ³	cm ³ x10 ²
Fermate + Pt	98.8a	79.4a	1.97a	375a	553a
Fermate + NI	98.3a	72.9b	1.82b	317b	469b
Triadimefon + Pt	98.1a	71.7b	1.81b	312b	456b
Triadimefon + NI	96.8a	71.2b	1.78b	310b	454b

¹Means in a column sharing a common letter are not significantly different according to Duncan's multiple range test ($P=0.05$).

²Seedling volume index = (root-collar diameter)² x height.

³Plot volume index = total seedling volume per plot.

Table 3.--Average of monthly rainfall readings at two rain gauge stations located 8 and 4 km from study site on the Savannah River Forest Station, Aiken, SC

Month	1984	1985
January	111	61
February	126	113
March	149	33
April	176	22
May	164	101
June	69	162
July	248	208
August	111	120
September	31	3
October	15	92
November	39	211
December	37	87
Total	1,276	1,213

Table 4.--The effects of triadimefon and fermate nursery sprays on the occurrence of fusiform rust galls on loblolly pine seedlings originating from the nursery through the second growing season in the field¹

Nursery spray	Seedlings with galls						Grand total
	Nursery origin			Field origin ^b			
	At 11ft ²	Latent ³	Total	Stem	Branch	Total	
	-	-	-	<u>Σ</u>	-	-	-
Triadimefon	0.3a	1.2b	1.5b	10.4a	12.2a	22.6a	24.1a
Fermate	0.5a	2.1a	2.6a	8.5a	7.7b	16.2b	18.8b

¹Within columns, means sharing a common letter are not significantly different according to chi-square analysis ($P=0.05$).

²Based on examination of 6,000 seedlings/spray treatment in the nursery.

³Stem galls less than 20 cm from the groundline detected after 1 year in field.

⁴Galls higher than 20 cm from the groundline or on branches detected after second year in field.

of the study was similar to the first but March, April, and September were relatively dry. No prolonged drought occurred during the study.

The degree of ectomycorrhizal development of the seedlings and root starch levels from the nursery did not affect fusiform rust disease. Ectomycorrhizal treatments, therefore, were combined to examine fungicide effects on rust disease. At the nursery stage, there was no difference in the incidence of fusiform rust galls on seedlings sprayed with either fungicide (table 4). Seedlings sprayed with ferimate, however, developed nearly twice as many galls as seedlings sprayed with triadimefon from latent nursery infections (2.1 vs. 1.2 percent of seedlings).

Surprisingly, seedlings sprayed with triadimefon developed significantly more field-origin galls than seedlings sprayed with ferimate (22.6 vs. 16.2 percent of seedlings). As a result, total rust gall development (nursery and field origin) was 28 percent greater on triadimefon-sprayed seedlings.

Discussion

In the 2 years after planting, seedlings that had been sprayed with triadimefon survived and grew as well as uninoculated seedlings sprayed with ferimate, even though the latter had significantly more nursery-origin ectomycorrhizae at planting. These field results agree with the previous results reported by Rowan and Kelley (1986). However, none of the seedlings in this study were subjected to soil moisture stress during their initial establishment. Rainfall averaged more than 145 mm/month and ranged from 69 to 248 mm/month during the first 8 months after planting. By the end of this period most seedlings, regardless of their initial complement of nursery-origin ectomycorrhizae, probably had similar amounts of ectomycorrhizae (Marx and Hatchell 1986).

The stimulating effect of *Pt* ectomycorrhizae on seedling growth on this

good-quality forest site was small in comparison with those observed on similar sites. The main difference is that very little soil moisture stress occurred during the present study, whereas soil moisture stress was moderate to severe in the others. Without soil moisture stress, seedlings with nursery-origin ectomycorrhizae, and even reduced amounts of *Pt* ectomycorrhizae, apparently can survive and grow as well as seedlings with abundant *Pt* ectomycorrhizae. When soil moisture stress after planting is high, seedlings with abundant *Pt* ectomycorrhizae grow faster than seedlings with nursery-origin ectomycorrhizae. The effects of *Pt* ectomycorrhizae and high root-starch levels on improved tree growth in the field cannot be separated at this time.

The greater incidence of fusiform rust galls on triadimefon-sprayed seedlings after 2 years in the field was unexpected. Triadimefon certainly was effective in controlling this disease in the nursery. The greater incidence of field-origin galls on these seedlings after 2 years in the field suggests, however, that seedling susceptibility to rust infection was higher after triadimefon spraying than after ferimate spraying for some reason. If it is confirmed in additional studies, this effect has important implications in loblolly pine plantations because trees that develop stem and branch galls before age 5 rarely reach maturity (Harms 1961; Sluder 1977). Rust incidence on these loblolly pine seedlings at age 2 is very high compared with reports from other plantings (Wells and Dinus 1978). Temperature and humidity during this study were obviously ideal for rust infection and gall development, and the planting site is in a zone of high rust hazard (Squillace 1976).

Readers are cautioned that these results are based on a single group of seedlings, grown in one nursery, and planted on one site with high rust hazard. These results, therefore, can only suggest a potential problem caused by long-term negative effects of a nursery-applied fungicide.

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